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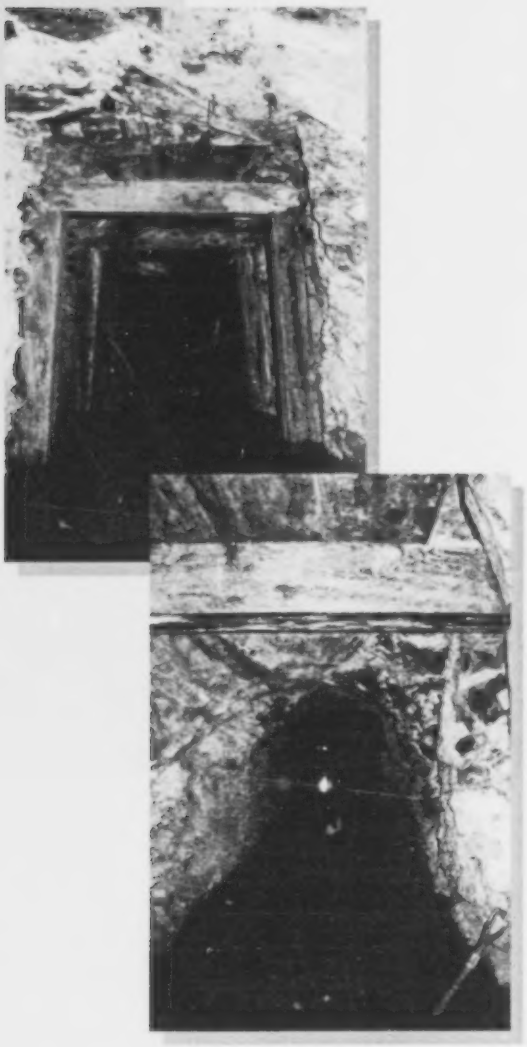
BRITISH COLUMBIA

Britannia Mine Remediation Hydraulic/Geotechnical Monitoring During 2004 Hydraulic Communications Test



Prepared for:

B.C. MINISTRY OF
SUSTAINABLE RESOURCE
MANAGEMENT

Prepared by:

KLOHN CRIPPEN

SRK Consulting
Engineers and Scientists

SRK Project Reference No:
1CB012.010.106

March 2005

105-04437/

Britannia Mine Remediation
Hydraulic/Geotechnical Monitoring During 2004 Hydraulic Communications Test

BC Ministry of Sustainable Resource Management

c/o Golder Associates Ltd
Suite 500,4260 Still Creek Drive
Burnaby, BC V5C 6C6

KLOHN CRIPPEN CONSULTANTS LTD.
Suite 500, 2955 Virtual Way
Vancouver, B.C. V5M 4X6
Tel: 604.669.3800 Fax: 604.251.8510
E-mail: gparkinson@klohn.com Web site: www.klohn.com

SRK CONSULTING (CANADA) INC.
Suite 800, 1066 West Hastings Street
Vancouver, B.C. V6E 3X2
Tel: 604.681.4196 Fax: 604.687.5532
Email: vancouver@srk.com Web site: www.srk.com

SRK Project Number 1CB012.010

March 2005

Authors
Graham Parkinson, P.Geo
Pat Bryan, P.Eng

Reviewed by
Peter Healey, P.Eng

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1 Introduction and Summary

This report presents the results of a hydraulic and geotechnical monitoring program that was carried out in conjunction with the 2004 Hydraulic Communication Test (HCT). SRK and Klohn Crippen conducted the HCT on the 4100 Adit during the summer of 2004 at the Britannia Mine.

Key objectives of the monitoring program were to confirm the storage capacity available in the mine workings and to measure the magnitude of drawdown effects on known restrictions to water flow.

The report also provides results of the geotechnical and 4100 instrumentation monitoring program, along with recommendations for ongoing maintenance and possible upgrades.

2 Mine Storage Capacity

The storage capacity determined during the 2002 Plug Test for levels between elevations of 20 m and 250 m was 408,000 m^3.

Mine storage was recalculated during the 2004 HCT. Mine inflows were first established by conducting inflow tests, which typically involved adjusting the outflow from the mine until the reservoir surface level remained more or less constant. The estimated inflows to the reservoir, together with the measured outflows at the 4100 plug, were used in a water balance to keep track of storage within the mine during the filling and draining phases of the 2004 HCT. The inferred storage levels were then compared against the corresponding measured reservoir elevations to determine the reservoir's height-capacity curve. Figure 2-1 presents the reconstructed water balance for the 2004 mine filling and draining phases, with the results of the inflow tests indicated. Figure 2-2 shows calibration corrections that were made to the 2004 record of water levels measured at the 4100 plug.

The 2004 mine filling rose to a higher elevation than in 2002 and ended at the spill point of the 3250 tunnel at a height of 266.3 m above the plug. The filling of the previously untested region between 250 m and 266.3 m added 33,000 m^3 of known storage to the mine reservoir, bringing the total measured volume between the true (density corrected pressure elevation above 6" pipe on plug) elevations of 20 m and 266.3 m to 441,000 m^3.

Table 2.1 presents the current best estimates of mine storage volume as a function of elevation above the 4100 plug.

Table 2-1: Adopted Height-Capacity Curve for the Mine Reservoir

Elevation above 6"Pipe in 4100 Plug [d]	Live Storage [a]
(m)	(1000 m^3)
20 [b]	0
50	56
100	143
150	229
200	318
250	408
267.1 [c, d]	441

Notes:

a) The storage values presented in this table were largely extracted from the height-capacity curve developed from data collected during the drain down phase of the 2002 plug test. Of the four independent determinations of the height-capacity curve, this one was probably the most accurate. The drain down occurred during a dry period and therefore the inflow record for the mine reservoir could be accurately estimated using weekly inflow tests. The storage available in the increment from 250 m to 267.1 m [d] was estimated from data collected during the drain down of the 2004 HCT. Dry conditions prevailed while this upper increment of the reservoir was being drained.

b) The storage from 0 m to 20 m is designated as a dead storage to prevent the floating of debris (primarily railway ties) down the 4100 adit towards the 4100 plug.

c) Water begins to spill from the mine reservoir to the 3250 adit at approximately 267.1 m above the 4100 plug (if pressure transducer readings are converted to equivalent depths using a density of 1000 kg/m^3).

d) The water level in the mine reservoir is measured indirectly by pressure measurements. The elevation values presented in this table assume the density of the water in the reservoir is 1000 kg/m^3. The true density will be slightly greater than 1000 kg/m^3 and this will result in true elevations that are slightly less than indicated in this table. For example, the apparent spill elevation of 267.1 m corresponds with a true elevation of 266.3 m.

Figure 2-3 shows comparison plots of the height-capacity curves developed using data collected in 2002 and 2004. During these two plug tests, a total of four independent determinations of the reservoir's height-capacity curve were made, one for each time the mine was filled and one for each time the mine was drained. The four curves presented on the plot agree well with one another, particularly in the upper levels of the reservoir above 100 m.

Since the overall accuracy of the volume determination method is estimated to be on the order of 10%, it is likely that no significant changes have occurred in storage.

3 Restrictions to Mine Outflows

The resistance of the mine restrictions can, in effect, be measured each time the valve at the 4100 plug is adjusted. Two cases are believed to provide the most accurate measurements of the resistance, namely:

- A valve opening after a prolonged period of zero release; and
- A complete valve closure after a prolonged period of release.

Each of these cases allows, either before or after the valve adjustment, a lengthy period in which the pressure in the outer portions of the mine reservoir (plug and raise) can equalize with the pressure in the internal portion of the reservoir (mine core). The stabilized pressure condition in each case serves as a reference level to measure the change in head after a valve adjustment.

The filling and draining of the mine during 2004 provided a number of opportunities to measure the resistance of the mine restrictions. Tables 3.1 and 3.2 list measurements of head loss across the restrictions that were made in 2002 and 2004, respectively. The data for 2002 are reproduced here to illustrate changes that have occurred over time in the resistance of the mine restrictions.

The observable behaviour of the 4100 mine reservoir can be approximated by a two tank hydraulic model. In this model, the 4100-3250 raise, located relatively close to the plug, has a small free surface area (about 28 m^2) and little apparent hydraulic restriction between it and the region of the plug. This outer region of the mine reservoir is connected to the much larger cross-sectional area (typically about 1,800 m^2) inner mining core by the relatively long (~5 km) and probably more restricted 4100 level tunnel and also via parallel connections between shafts in the mine's lower permanently flooded levels below the 4100 level.

Once the core water level has equalized with the indicated level at the plug, any drawdown caused by releasing water from the 4100 plug is equal to the pressure drop across the mine restrictions. The pressure drop that appears as the valve is opened is caused by the difference in water level needed (between the drawn down level in the raise area and the relatively static water level in the core) to mobilize water flow out of the mine through the restrictions.

Table 3-1: Estimated Resistance of Internal Mine Restrictions in 2002

Date	Observed Outflow (L/s)	Estimated Head Differential (m)	Internal Gradient (m per 100 L/s)	Reservoir Level [a]
2002 Apr 19	97 [b]	8.7	9.0	77
2002 Apr 19	190	17	8.9	77
2002 Apr 24	50	4.1	8.2	101
2002 Jun 10	370	40	10.8	90
2002 Jun 14	350	38	10.9	180
2002 Jun 24	350	31	8.9	209
2002 Jul 15	303	20.3	6.7	110
2002 Jul 26	152	6.3	4.1	187
2002 Aug 01	101 [c]	3.0	3.0	207
2002 Aug 07	98	2.8	2.9	230
2002 Aug 13	83	2.3	2.8	250
2002 Aug 27	233	14.5	6.2	145
2002 Sep 05	237	17.3	7.3	114
2002 Sep 13	102 [b, c]	3.4	3.3	73
2002 Sep 23	50	1.4	2.8	30
2002 Oct 03	41	0.83	2.0	22

Note: a) Based on measured pressure at 4100 plug, during periods of no outflow from plug.

b) The character of the mine resistance-flow relationship changed suddenly during the spring freshet of 2002. This is illustrated by comparing the resistances observed on April 19 and September 13. On both dates, the reservoir levels and release rates were similar. However, the head differentials were markedly different. On April 19, 8.7 m of head was required to pass 97 L/s. This reduced to 3.4 m on September 13 to pass a slightly larger flow.

c) At some point between June 24 and July 15, the mine hydraulics started following a turbulent flow law. Evidence exists to suggest that the resistance-flow relationship is independent of the water level in the mine. On August 1 and September 13 water was released from the plug at rates of about 100 L/s. The two release rates resulted in similar head differentials despite the fact that the water levels in the mine were quite different (207 m vs. 73 m).

Table 3-2: Estimated Resistance of Internal Mine Restrictions in 2004

Date	Observed Outflow (L/s)	Estimated Head Differential [a] (m)	Internal Gradient (m per 100 L/s)	Reservoir Level
2004 Jan 13	78	4.8	6.2	38
2004 Jan 15	90	6.0	6.7	43
2004 Jan 19	111	7.0	6.3	66
2004 Mar 10	62	2.9	4.7	27
2004 Mar 11	58	2.5	4.3	30
2004 Jun 04	294	35	11.9	76
2004 Jun 04	304	37	12.2	81
2004 Jul 26	84	3.9	4.6	134
2004 Sep 23	66	2.4	3.6	264
2004 Sep 25	51	1.4	2.7	264
2004 Sep 26	53	1.4	2.6	265
2004 Oct 01	339	38	11.2	246
2004 Oct 01	268	21	7.8	250
2004 Oct 21	279	29	10.4	95
2004 Nov 01	116	6.4	5.5	35
2004 Nov 02	131	7.6	5.8	38

Note: a) The resistance-flow relationship continued to follow a turbulent flow law in 2004. For a given flow rate, the resistance in 2004 was about 60% greater than observed in the latter half of 2002.

By plotting the pressure drop against the flow rate created by various valve openings a relationship between these two variables can be established. The magnitude and type of the restriction (i.e. laminar or turbulent flow law) can be interpreted from the best-fit curve through the data points.

The currently observed 2004 (best-fit) relationship for estimating head differential is:

$$H = 0.0027\ Q^{1.65}$$

where H represents the head difference across the mine restrictions in metres and Q is flow in l/s. In this equation the best-fit exponent (1.65) matching the observed data gives an indication of the type of flow regime. Values produced by this relation are presented in Table 3.3 below.

Table 3-3: Restriction Head Loss vs. Flow Rate

Flow (l/s)	Head Loss across Restrictions (m)	Measured (M) or Extrapolated (E)
0	0.0	
100	5.4	M
200	16.9	M
280	29.5	M
300	33.0	M
400	53.1	M
500	76.7	E
600	104	E
700	134	E
800	167	E
900	202	E
1000	241	E

For example, to pass 280 l/s requires establishing 29 m of head between the mine core and the region immediately behind the plug. In 2002, the same flow required only a head differential of 18 m, thus the magnitude of the restriction has increased by about 60% between 2002 and 2004, however the actual values of both the coefficient and exponent of the head-discharge relationship tend to fluctuate within each year, depending on the recent flow history in the mine (see Figure 3-1 Historical Changes in Resistance of Internal Mine Restrictions).

For a laminar flow system (corresponding to slow flow through a fine media such as sand), one would expect head loss across the restrictions to vary linearly with discharge from the 4100 plug (i.e., $H \alpha Q$). For fully turbulent flow (corresponding to larger openings experiencing higher velocities), the head loss would be expected to increase with the square of the discharge (i.e., $H \alpha Q^2$). Based on the value of the exponent part of the best-fit relation, the current restriction appears to follow a turbulent flow law more closely than a laminar one. In the early part of the 2002 plug test, before the mine was completely filled, the flow was more laminar. The flow regime then suddenly changed to a turbulent type flow system (i.e. larger openings) after a significant release of water had

been made from the mine reservoir during the 2002 freshet. A potential reason for the sudden change in regime is outlined below.

The restrictions are postulated to consist of two physical components:

- a gradually accumulating "permanent" component (i.e. rock falls, etc.) causing partial blockages; and
- a more variable, sludge-based component, which is preferentially deposited under certain geochemical conditions behind sites created by the "permanent" component.

The first component may only be permanent in a relative sense. Its structure would undoubtedly be more difficult to disrupt than the sludge-based component. However, the possibility exists that the first component may not necessarily lead to a progressively increasing resistance within the mine. The resistance could be lessened by the rotting of timbers or the occurrence of piping failures.

It appears that the second, possibly sludge-based component can be washed out. The observed change in regime from laminar to turbulent in 2002 may have resulted from such a wash out. Monitoring of turbidity versus changes in flow rates may assist in verifying this relationship. Large increases in turbidity were seen after the commencement of the draindown during the two plug tests.

The most likely scenario inside the mine is that the water is being impeded at many separate locations by sludge backing up in many different ways including deposits against piles of railway ties, collapsed timber sets, rock falls from the back and walls of tunnels, collapsed ore chutes, partially collapsed stopes, raises filled with blasted rock, waste rock backfill placed in stopes, caved rock, etc. These would be at various (somewhat random) locations distributed throughout the old workings (tunnels, stopes and raises) between 4100 and 3250 levels.

One possible explanation of the observed flow behaviour in the mine is that there are two or more significant parallel paths through the mine, each with a different type of restriction and each resulting in a different flow regime becoming apparent at differing flow rates. These paths can be alternately blocked by or be free of sediment. This mechanism could account for the observed changes in behaviour corresponding to intermittent divisions of the flow from the core between direct flows via the 4100 tunnel, and alternate paths which allow flow to pass through the lower mine levels via the shafts.

There appears to be no systemic variation in the magnitude of the observed restrictions with reservoir level (see Figure 3-2). Therefore, it is likely that the majority of the restrictions are located within the permanently flooded sections of the mine, i.e. in the 4100 tunnel and in the lower levels of the mine.

Restrictions existing above the flooded parts of the mine reservoir, i.e., above the 3250 level, would not affect the pressure-flow regime seen at the plug but would act to create impoundments contributing to the 5-day delay in the response of the mine levels seen after peak surface water inputs to the mine openings.

The 2002 plug test and the 2004 HCT offered the chance to examine two "snapshots" of the behaviour of the mine's internal hydraulics. The differences observed between and within these two test sequences revealed the dynamic behaviour of the mine's internal hydraulics. Monitoring of this behaviour should become a routine element of the reservoir operational procedures as continued passage of waters to the 4100 portal is key to the current treatment process.

4 Geotechnical Monitoring of 4100 Level Plug

4.1 4100 Plug Geotechnical Inspections

Geotechnical conditions and plug stability indicators were monitored during the 2004 filling by regular site inspections conducted by Terry Johnson, Mine Manager and Graham Parkinson of Klohn Crippen. The frequency of the visits varied from weekly when reservoir levels were above 50 m, to daily when levels were above 200 m.

Objectives of the inspection visits were to check for any signs of increased seepage, seepage appearing in new location, any turbidity in seepage (indicator of fines washout), any spalling of rock or other unusual conditions. The condition of the instrumentation and piping was also examined during inspections.

None of the above indications of distress of the plug were noted during the 2004 mine reservoir filling.

As in 2002, the only seepage detected above the background drip rate of the tunnel was in the area of the north wall of the tunnel, adjacent to the piezometer collar. This seep flow on the wall of approximately .005 l/s was nearly constant regardless of variations in the reservoir level. Similar levels of seepage were seen during the 2002 mine filling.

No discrete seepages were noted on the contact area of the plug or on the plug face.

4.2 4100 Plug Area Tunnel Wall Piezometer

The 4100 tunnel wall piezometer was installed in advance of the 2002 plug test and was placed to monitor the hydraulic gradient and pressures in the downstream section of the tunnel wall adjacent to the plug.

As the section of formation rock tested by the piezometer is located in the downstream third of the rock surrounding the plug, lower piezometer pressures relative to reservoir pressures are an indication of an intact and effective upstream grout ring seal around the plugs upstream face and the presence of good clear drainage in the area of rock around the downstream face of the plug.

As part of improvements before the 2002 plug test a radial ring of split set lined 1.5" diameter drainage relief holes were placed around the downstream face of the plug to depths of 2m in 2002 to

reduce the near surface pressure gradient (tunnel to formation) and to reduce any tendency of tunnel wall rock to spall under formation pressures.

During 2004, the piezometer pressure transducer and manual gauge were checked on each visit and found to agree closely, indicating that these were functioning correctly.

During the 2002 filling and during the early parts of the 2004 filling, the piezometer generally climbed from a background of 110 kPa (probably a groundwater induced, formation background pressure) at reservoir level 20 m with increasing reservoir pressure to a peak piezometer pressure of 160 kPa at the peak of the filling to 266 m.

Using the total piezometer pressure rise of 50 kPa above background and the peak reservoir pressure of 2615 kPa at 266 m filling, we can note that the normal tunnel wall piezometer response is linear, with an additional piezometer pressure response seen from filling of about 1/50th that of pressure in the main reservoir

As the 2004 reservoir filling neared peak levels, readings on the piezometer began to sporadically and suddenly drop in pressure with slower returns back more normal levels as the mine reservoir level continued to climb. These sudden pressure drops are labelled on Figure 4-1 4100 Tunnel Wall Piezometer response.

After consideration of the readings by staff from Klohn Crippen and Golder Associates, it was concluded that the rubber piezometer seal may be suffering from poor confining pressure in a fractured zone and that either joints in the formation rock or rubber seal were likely periodically letting go under the higher than previously experienced piezometer pressures, resulting in the sudden drops in indicated piezometer pressure.

As water is very incompressible, a tiny change in volume of the piezometer tested zone causes a large change in piezometer pressure. Since the piezometer pressures recovered slowly after each sharp drop, it was considered that there was still very little hydraulic communication with the much higher pressure reservoir zone (acting as the source of the normal piezometer pressure) as otherwise the piezometer pressure would have recovered more quickly.

Piezometer readings are recorded in the cumulative 2004 4100 Level Excel data file.

The seepage around the tunnel wall piezometer was sampled in February 2004 as part of the investigation into the geochemistry of the 4100 tunnel seeps, initiated to assist with prediction of corrosion rates in roof supports.

The pH of the water emanating from the piezometer collar region was near neutral (6.83) compared to mine water (ph 3.7 to pH 4.0) indicating that most of this seepage water is groundwater rather than the much lower pH reservoir water. Sulphate in the seep at the piezometer was slightly elevated (46 mg/L) compared to other seeps further from the plug (typically 30 mG/L) suggesting some mixing of reservoir water with groundwater in the formation.

4.3 Displacement Gauges

The displacement gauges were not functional during the 2004 mine filling as they were installed only to monitor plug stability as part of the temporary plug test and the configuration for the permanent plug instrumentation had not been finalized. The cases and connectors on the temporary displacement gauges on the plug face and the 10" pipe had corroded away and were not replaced by the owners as no significant displacements had been recorded during the 2002 plug test and plug stability was found to be satisfactory.

Only very small deformations of the plug face and tunnel geometry measured were detected during the 2002 plug test using Linear Variable Displacement Transformer sensors (LVDT). Although nominally sensitive to a small fraction of a mm, it was found that the LVDT sensors are also very sensitive to noise, vibration and the electrical environment and were consequently not reinstalled in the same temporary configuration.

A permanent plug displacement monitoring system would be better if installed closer to the centre of the plug face, using a more massive pier and sensor support linkage to better resist false signals from aliasing of vibrations caused by water flow in the nearby pipes.

The LVDT sensors would give better service if immersed in an oil bath to reduce corrosion. A relatively viscous oil would be best to dampen vibration of the small iron core which moves within the coils to indicate displacement. The oil bath would also act as a thermal mass, reducing daily thermal effects as air circulation varies in the tunnel. Digital filtering is also useful to dampen out extraneous influences on displacement data.

The LVDT AC drive bridges need to be separated from the data logger enclosure to reduce crosstalk, AC noise and ground loop problems which caused variations in the DC 4-20 mA displacement signal. The use of an isolation transformer may help to further reduce persistent small signal ground problems.

5 Hydraulic Monitoring of 4100 Plug / 4150 Drainage Tunnel

5.1 4100 Mine Reservoir Level Pressure Sensor

During maintenance calibration done on July 23, 2004 before the peak of filling for the Hydraulic Communication test, it was found that the Rosemount pressure sensor for the mine reservoir level would not accept a calibration value as the necessary correction was outside the sensors internally specified linearization range.

The sensor was replaced on September 8, 2005 with a factory calibrated unit as the stainless corrosion isolation membrane was perforated from contact with the mine water. The replacement sensor was equipped with a Hastealloy membrane, recommended as being more resistant to pitting or stress related corrosion. The replacement sensor was also installed with a charge of mineral oil filling the 18" riser pipe. As the mineral oil will float on the mine reservoir water, additional isolation from corrosion will be supplied by the oil column

Reservoir raw pressure and metres head are recorded in the cumulative 2004 4100 Level Excel data file. The corrections required as a result of the sensor replacement are illustrated in Figure 2.2

5.2 4150 Level Drainage Water Level Sensor

The sensor for the 4150 level drainage water level monitor was moved further into the 4150 tunnel, inside the old sandbag dam, as it was realized that surface waters caused significant variations in water levels for the region outside of the sandbag dam. In the new location, the sensor is much more responsive to changes in the actual level of the 4150 drainage level. Levels and elevations of the sensors and dams in the 4150 as verified by survey work in the tunnel completed in February 2005 are shown in Figure 5.1.

Before the 4150 level sensor was moved, occasional high water level readings (up to 1.4 m) were experienced. These occurred during periods of high surface water inflow which entered the ore pass raises and drained into the space between the sandbag dam and the stop log dam. At these times, the sandbag dam overtops back into the main 4150 level resulting in an apparent freeboard at the stop log dam of 24 inches.

Now that the integrity of the 4150 portal stop log dam has been confirmed, it would be desirable to further breach the internal sandbag dam to prevent high water levels being retained against the stop log dam.

Figure 5.2 shows the elevations of structures and water levels in the 4150 relative to the Roclink readings. Overtopping of the 2.1m high 4150 stop log dam would occur at about 1.8 metres as

indicated by the 4150 depth sensor. Typical readings of the 4150 depth sensor were in the range of 0.6 m at low flows to 1.0 m at flows near 350 l/s.

4150 level readings are recorded in the cumulative 2004 4100 Level Excel data file.

5.3 Seepage Flow meter

The 1.5 inch diameter magnetic flow meter flow tube installed on the seepage dam downstream of the plug continued to be useful to monitor flows for excess seepage or pipe leaks. Although this flow tube is too large to be accurate to capture variations in leakage due to changes in reservoir level, it has served well to detect several pipe fitting leaks that formed in area above the seepage dam.

Seepage flow meter readings are recorded in the cumulative 2004 4100 Level Excel data file.

5.4 4100 Plug Flow Meter and 4100/4150 Weir Flow Measurements

The 4100 Plug magnetic flow meter was electronically recalibrated in the spring of 2004 by Norpac. The tunnel flows were cross checked against both the 4150 Parshall flume and 4100 concrete rectangular weir stage records which are recorded by the Star logger located in the instrument shed near the 4100 portal. Rating curves for the flumes were checked using a stream flow meter to profile velocities.

Magnetic flow meter readings are recorded in the cumulative 2004 4100 Level Excel data file.

Indications from the calibrated flume readings were approximately 10% higher than those recorded by the calibrated magnetic flow meter. It is not clear if this reflects the slightly higher flow at the flumes (due to 4100/4150 tunnel seepages) or if this is a systemic calibration issue.

Parshall flume stage and flow indications are recorded in a separate Excel data file.

5.5 Water Sampling Pipeline and Pressure Reducers

Several water treatment pilot plant experiments were operated with mine reservoir water during the 2004 mine filling. This water was delivered to the portal by a 1.5 inch poly water sampling pipeline hung on the airline supports of the 4100 tunnel.

The sampling pipeline is fed by a series of three stainless steel ½" pressure regulators each set to drop up to 100 psi per stage, resulting in a design pipeline pressure of less than 60 psi. The small continuous flow from the pipeline passes through the online turbidity meter.

The regulators were reconfigured by the water treatment plant bidding parties several times to get more flow into the pilot plants during the mine filling. As a result the regulator assembly experienced several leaks due to the use of unsuitable fittings. The regulators were reassembled with all stainless fittings and the leakage issues were resolved.

5.6 Control Valve and Spray Shield

During the filling phase one incident occurred in which the 115 VAC powered valve actuator was found to be unable to move the 8" ball valve mounted on the 10" pipe at heads greater than approximately 255 m. This may have been due to sediment accumulated in the valve during the long period of valve closure or due to the extra load on the valve due to the higher pressures relative to the 2002 filling. Once the valve was cycled several times with the gate valve closed, and after torque limits were adjusted to 100% available torque from the actuator, the valve again moved freely under all loads up to the 266.3 m peak of the filling.

Vaive openings are recorded in the 2004 cumulative 4100 Level Excel data file.

The stainless steel spray shield performed well and showed no signs of corrosion or erosion.

6 Recommendations

- Implement a monitoring program to test the resistance of the mine restriction each year;
- Use flow and pressure measurements to improve the accuracy of the height-capacity curve each year. A full plug test (with detailed inflow tests) is recommended every 5-10 years to verify that changes have not occurred in actual mine storage;
- Update 4100 data logger and instruments to display elevations based on s.g.=1.0029 rather than 1.0000 so indicated 3250 spill elevations match HCT test levels;
- Breach 4150 sandbag dam to reduce accumulation of surface water between dams to lower seepage from 4150 south portal;
- Upgrade plug seepage flow meter to detect the lower flow rates of seepage flows;
- Install additional remote monitored piezometer at 4100 plug adjacent to present site. Installation can be done during drilling done for rock bolting program. Purpose is to be able to confirm stability of formation pressures and offer comparison with existing instrument in case of fluctuations;
- Incorporate monitoring program, geotechnical inspection guidelines and mine inflow forecast model into an Operations Manual for Mine Reservoir, and
- Periodically schedule a high flow rate, partial drain down to wash out accumulated sludge and to prevent possible solidification of sludge in tunnels into a permanent blockage.

This report, **1CB012.010 – Britannia Mine Remediation, Hydraulic/Geotechnical Monitoring, During 2004 Hydraulic Communications Test**, has been prepared by:

Graham Parkinson, P. Geo
Klohn Crippen Consultants Ltd.

Pat Bryan, P. Eng.
Associate Hydrologist

Peter Healey, P. Eng
SRK Consultants Ltd.

7 References

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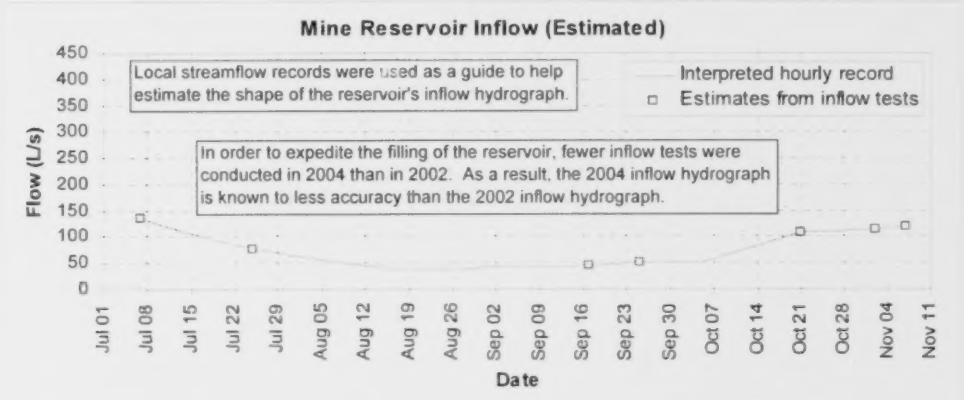
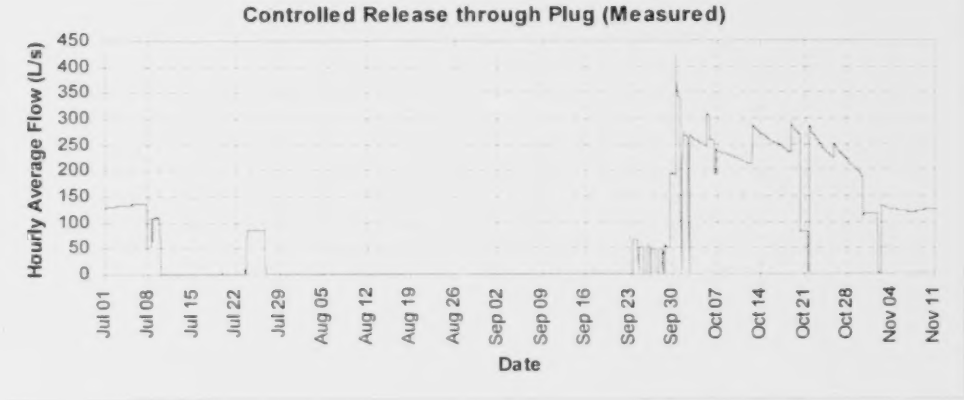
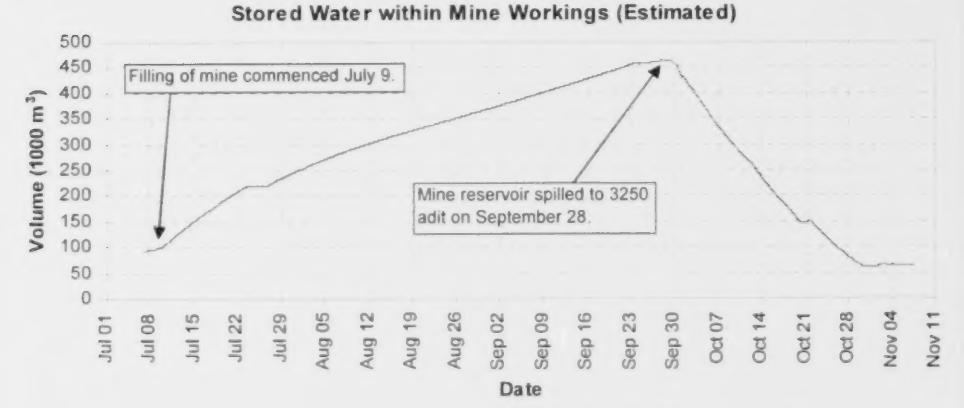
Figures







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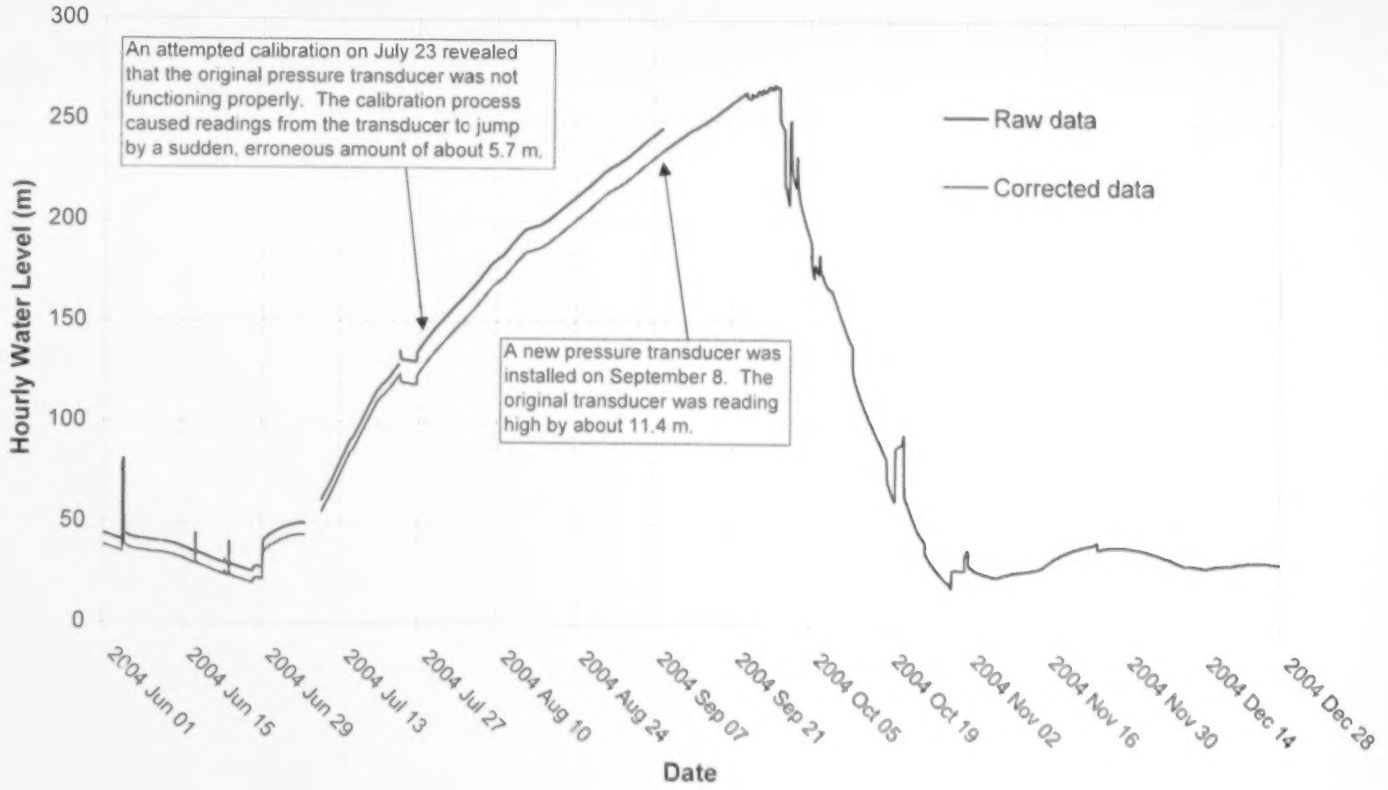
Ministry of Sustainable Resource Management
BRITISH COLUMBIA

Britannia Mine Remediation
Hydraulic/Geotechnical Monitoring Program

Water Balance for 2004 HCT

PROJECT	DATE	APPROVED	FIGURE
1CB012.010	March 2005		2-1

Fig 2.1_2.2_HCT_1CB012.010_pjb_Rev1.xls


An attempted calibration on July 23 revealed that the original pressure transducer was not functioning properly. The calibration process caused readings from the transducer tc jump by a sudden, erroneous amount of about 5.7 m.
A new pressure transducer was installed on September 8. The original transducer was reading high by about 11.4 m.
Raw data
Corrected data
Hourly Water Level (m)
300
250
200
150
100
50
0
2004 Jun 01
2004 Jun 15
2004 Jun 29
2004 Jul 13
2004 Jul 27
2004 Aug 10
2004 Aug 24
2004 Sep 07
2004 Sep 21
2004 Oct 05
2004 Oct 19
2004 Nov 02
2004 Nov 16
2004 Nov 30
2004 Dec 14
2004 Dec 28
Date

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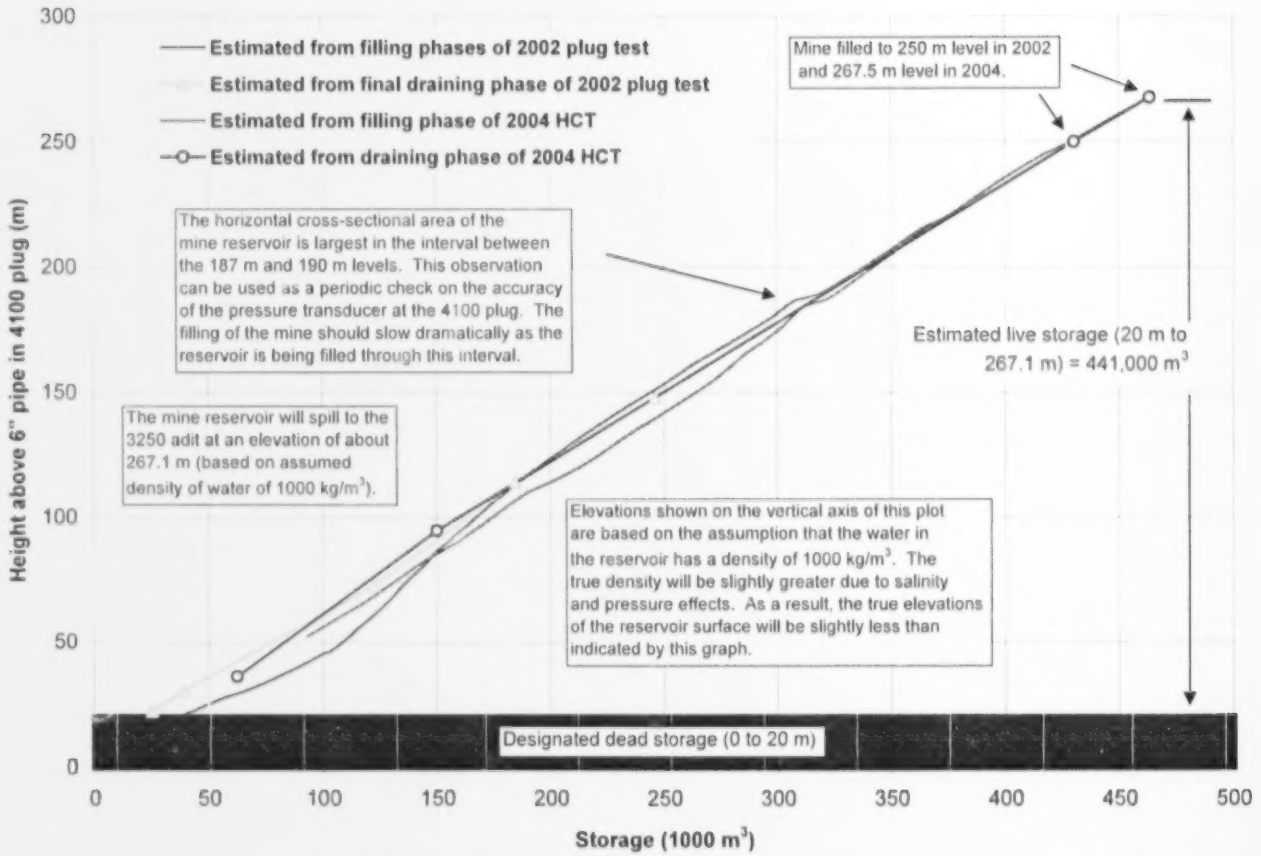
Corrections made to Water Level Records at 4100 Plug

PROJECT	DATE	APPROVED	FIGURE
1CB012.010	March 2005		2-2

Fig. 2.1_2.2_HCT_1CB012.010_pjb_Rev1.xls


Estimated from filling phases of 2002 plug test
Estimated from final draining phase of 2002 plug test
Estimated from filling phase of 2004 HCT
Estimated from draining phase of 2004 HCT
Mine filled to 250 m level in 2002 and 267.5 m level in 2004.
The horizontal cross-sectional area of the mine reservoir is largest in the interval between the 187 m and 190 m levels. This observation can be used as a periodic check on the accuracy of the pressure transducer at the 4100 plug. The filling of the mine should slow dramatically as the reservoir is being filled through this interval.
Estimated live storage (20 m to 267.1 m) = 441,000 m3
The mine reservoir will spill to the 3250 adit at an elevation of about 267.1 m (based on assumed density of water of 1000 kg/m3).
Elevations shown on the vertical axis of this plot are based on the assumption that the water in the reservoir has a density of 1000 kg/m3. The true density will be slightly greater due to salinity and pressure effects. As a result, the true elevations of the reservoir surface will be slightly less than indicated by this graph.
Designated dead storage (0 to 20 m)
Height above 6" pipe in 4100 plug (m)
Storage (1000 m3)
0
50
100
150
200
250
300
350
400
450
500

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Independent Estimates of Mine Reservoir Height/Capacity Curve

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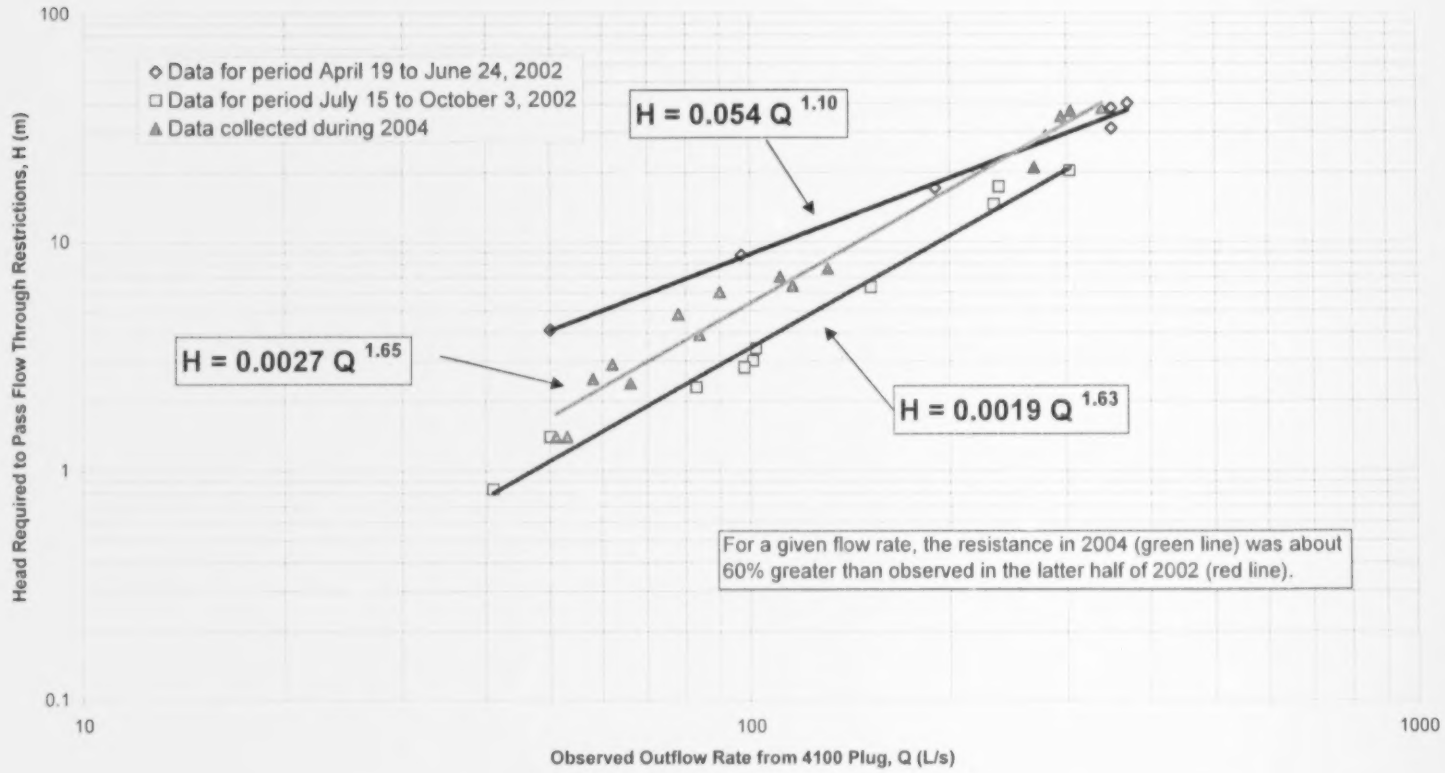
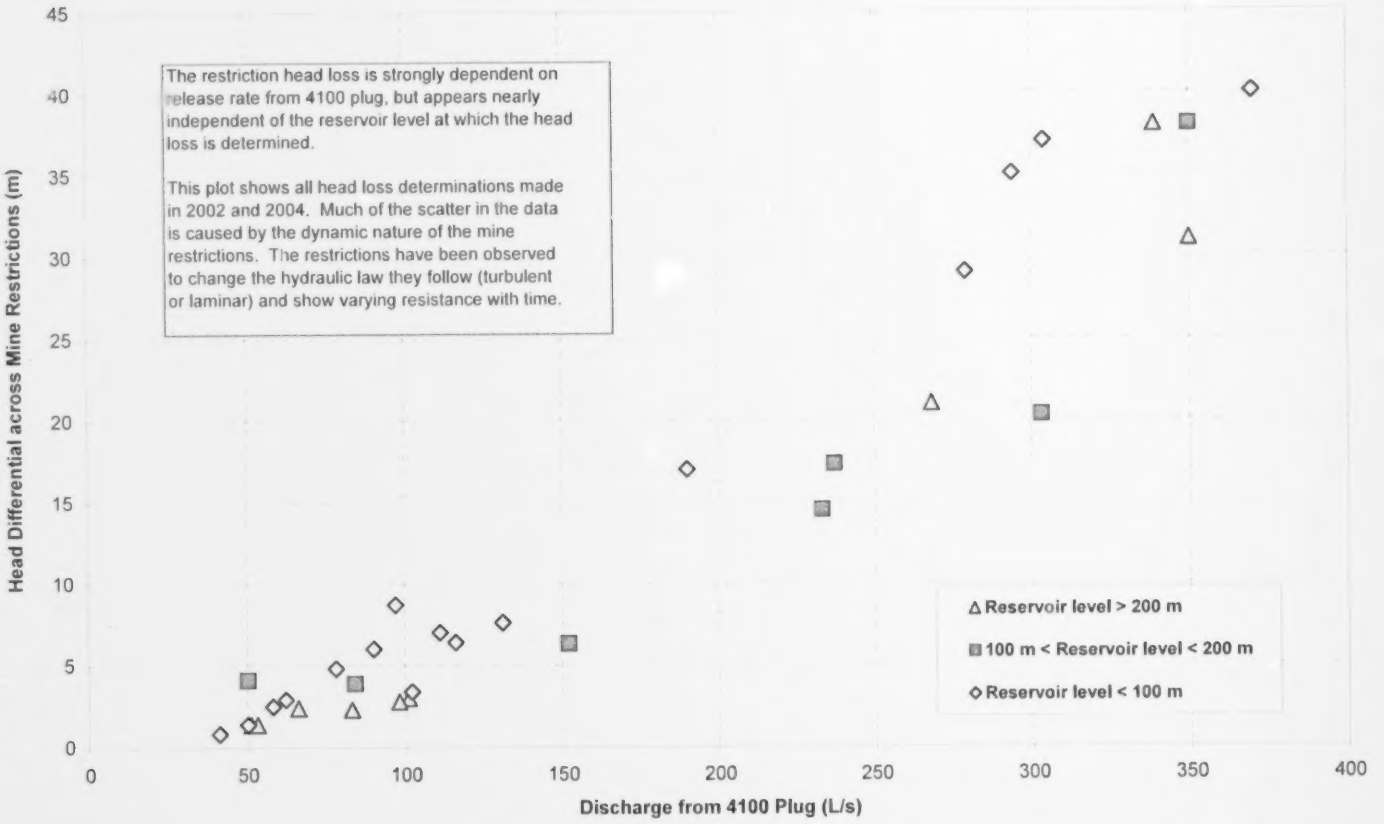
Fig 2.3_ Reservoir Storage-Capacity Curve_Rev1


◇ Data for period April 19 to June 24, 2002
□ Data for period July 15 to October 3, 2002
▲ Data collected during 2004
H = 0.054 Q 1.10
H = 0.0027 Q 1.65
H = 0.0019 Q 1.63
For a given flow rate, the resistance in 2004 (green line) was about 60% greater than observed in the latter half of 2002 (red line).
Head Required to Pass Flow Through Restrictions, H (m)
100
10
1
0.1
10
100
1000
Observed Outflow Rate from 4100 Plug, Q (L/s)

SRK Consulting Engineers and Scientists; Klohn Crippen	Britannia Mine Remediation Hydraulic/Geotechnical Monitoring Program			
Ministry of Sustainable Resource Management, British Columbia	**Historical Changes in Resistance of Internal Mine Restrictions**			
	PROJECT 1CB012.010	DATE March 2005	APPROVED	FIGURE **3-1**

Fig 3.1_Hydraulic Resistance of Blockage_1CB012.010 Rev02.xls


The restriction head loss is strongly dependent on release rate from 4100 plug, but appears nearly independent of the reservoir level at which the head loss is determined.
This plot shows all head loss determinations made in 2002 and 2004. Much of the scatter in the data is caused by the dynamic nature of the mine restrictions. The restrictions have been observed to change the hydraulic law they follow (turbulent or laminar) and show varying resistance with time.
Head Differential across Mine Restrictions (m)
Discharge from 4100 Plug (L/s)
0
5
10
15
20
25
30
35
40
45
0
50
100
150
200
250
300
350
400
Δ Reservoir level > 200 m
■ 100 m < Reservoir level < 200 m
◇ Reservoir level < 100 m

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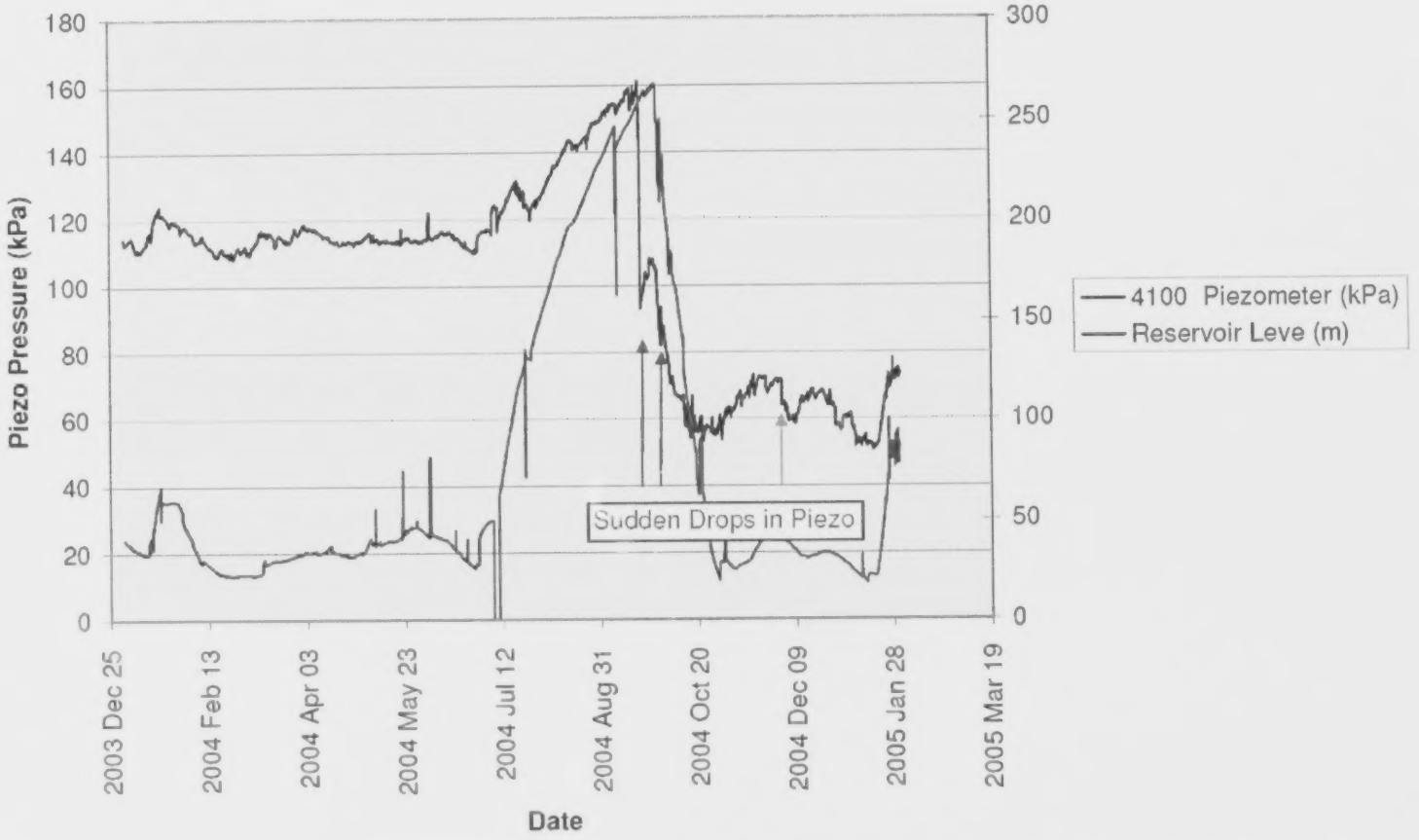
Cross plot of gradient induced by restrictions vs Mine Elevation

PROJECT	DATE	APPROVED	FIGURE
1CB012.010	March 2005		3-2

Fig 3.2_mine_ restrictions.xls



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4100 Tunnel Wall Piezometer Response in 2004

PROJECT:	DATE:	APPROVED	FIGURE:
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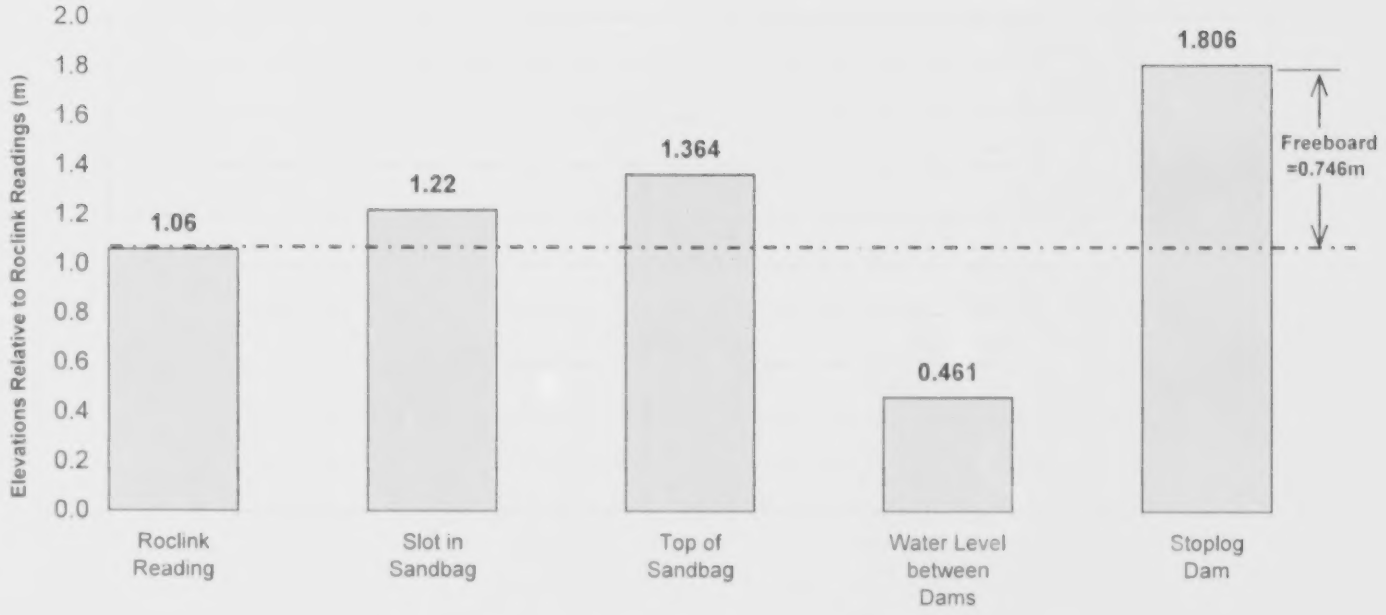

Relative Elevations in 4150 Tunnel (compared to Roclink Readings)

Note: All reading taken on February 3 and 4, 2005

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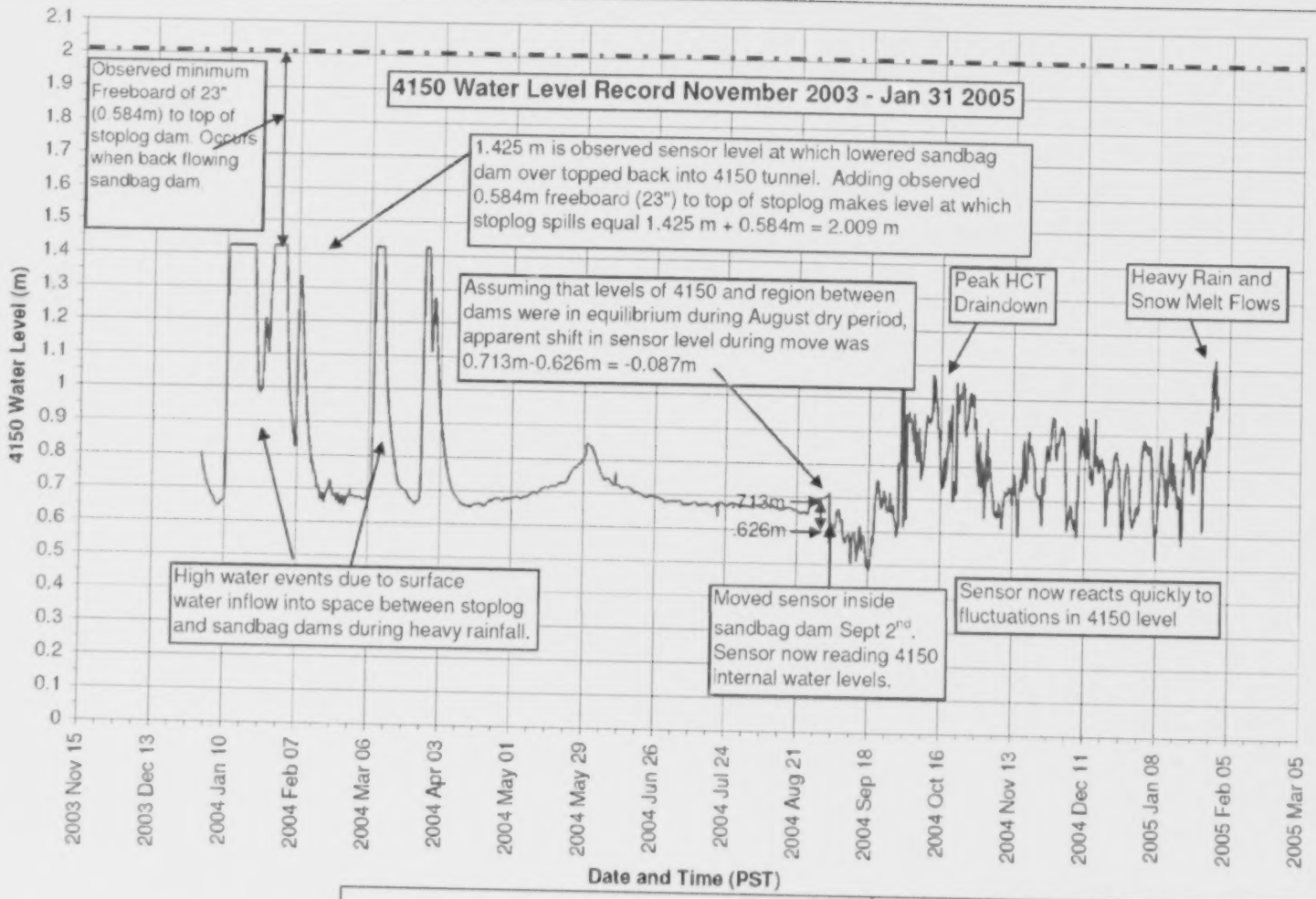
Relative Elevations in 4150 Tunnel

PROJECT	DATE	APPROVED	FIGURE
1CB012.010	March 2005		5-1

FILE REF: Fig 5.1_February 2005 Trip_1CB012.010_km_Rev1.xls


4150 Water Level Record November 2003 - Jan 31 2005
Observed minimum Freeboard of 23" (0.584m) to top of stoplog dam. Occurs when back flowing sandbag dam
1.425 m is observed sensor level at which lowered sandbag dam over topped back into 4150 tunnel. Adding observed 0.584m freeboard (23") to top of stoplog makes level at which stoplog spills equal 1.425 m + 0.584m = 2.009 m
Assuming that levels of 4150 and region between dams were in equilibrium during August dry period, apparent shift in sensor level during move was 0.713m-0.626m = -0.087m
Peak HCT Draindown
Heavy Rain and Snow Melt Flows
.713m
.626m
High water events due to surface water inflow into space between stoplog and sandbag dams during heavy rainfall.
Moved sensor inside sandbag dam Sept 2nd. Sensor now reading 4150 internal water levels.
Sensor now reacts quickly to fluctuations in 4150 level
4150 Water Level (m)
2.1
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
2003 Nov 15
2003 Dec 13
2004 Jan 10
2004 Feb 07
2004 Mar 06
2004 Apr 03
2004 May 01
2004 May 29
2004 Jun 26
2004 Jul 24
2004 Aug 21
2004 Sep 18
2004 Oct 16
2004 Nov 13
2004 Dec 11
2005 Jan 08
2005 Feb 05
2005 Mar 05
Date and Time (PST)

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4150 Drainage Level Record for 2004

PROJECT:	DATE:	APPROVED:	FIGURE:
1CB012.010	March 2005		5-2